MICROSCOPIC STUDIES ON THE CENTRAL NERVOUS SYSTEM OF REPTILES AND BATRACHIANS.

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ARTICLE IV.

DIAMETERS OF THE NUCLEI IN THE NERVE CELLS WHICH ARE RELATED TO MOTOR NERVES (*continued*):[1] CHELYDRA SERPENTINA (SNAPPING TURTLE); IGUANA TUBERCULATA (IGUANA); PHRYNOSOMA CORNUTUM (HORNED TOAD); MENOPOMA ALLEGHENIENSE (HELLBENDER); SIREN LACERTINA (SIREN); DIEMYCTYLUS TOROSUS (SALAMANDER) AND SERPENTS.

AS in former articles, the average diameters are given in divisions of Nachet's micrometer eye-piece with his objective No. 5, and as most of the nuclei are oval, as seen in sections, two dimensions are noted.

CHELYDRA SERPENTINA.

Spinal cord, cervical enlargement, . . .	7.	x 8.
" " lumbar "	7.	x 8.
Origin of the motor root of the trigeminus . .	7.	x 8.
" " oculomotorius and trochlearis . .	4.	x 5.

IGUANA TUBERCULATA.[2]

Spinal cord, cervical enlargement . . .	5.5	x 6.
" " lumbar "	6.	x 6.5

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[1] Jan., 1880, July, 1880, and Jan., 1881, this JOURNAL.

[2] The writer is aware that these figures are at variance with some statements published recently by Dr. E. C. Spitzka, this JOURNAL, April, 1881; *Science* vol. i, No. 7, and vol. ii, No. 34.

Origin of the motor root of the trigeminus	5. x 5.5
" " oculomotorius and trochlearis	4. x 4.5

In phrynosoma the ratio of the nuclei dimensions is about the same as in the iguana, with the exception of the spinal cord, where little or no difference exists between the average size of the cervical and lumbar nuclei.

1. While in the snapping turtle the nuclei in the cells of the two spinal-cord enlargements do not differ materially in size, in the iguana those of the lumbar are half a division larger than those of the cervical region. This corresponds with the apparent power of the extremities.

2. While in the snapping turtle the nuclei in the cells of origin of the oculomotorius are more than three divisions smaller than those in the motor-trigeminal cells, in the iguanidæ this difference in size is reduced to one division.

In Article III of this series I have given the diameters of the cell nuclei of the alligator (three feet long) as follows:

Spinal cord, cervical enlargement	6.5 x 7.5
" " lumbar "	6.5 x 7.5
Origin of the motor root of the trigeminus	6. x 7.
" " oculomotorius	5. x 5.

The specimen of iguana which I have studied measured 3 feet 2 inches in length; the antero-posterior diameter of its eyeball was ¾ of an inch, and its jaw muscles were not strikingly well developed.

The comparative differences in size between the oculomotor and motor-trigeminal nuclei, therefore, correspond more closely with jaw-muscle development than with that of the eye-muscles.

I find nothing in the nervous system of the iguanidæ but evidence additional to that already observed in favor of my views, and doubt whether a more striking confirmation of my conclusions can be found than is furnished by the facts denoted by the above measurements, giving due consideration to the habits and conformation of the different animals.

The relative size and arrangement of the cerebellum, optic and cerebral lobes in the iguanidæ are shown in my photograph of a vertical longitudinal section through the brain of phrynosoma. This plate was published in November, 1880, and can be examined at several libraries, including that of the New York Academy of Medicine. The cerebellum is seen to curve forward over, and to be closely applied to, the optic lobes. The same thing is true in the iguana, although the cerebellum is more flattened and extends a little farther forward.

In heloderma this organ also curves forward but is not closely applied to the optic lobes.

In anolius the cerebellum very closely resembles that of phrynosoma in all respects.

The spinal cord of the iguana, in external form, differs from that of the alligator in one interesting particular, viz., in the horizontal transverse diameter of the lumbar enlargement. While in the latter animal the diameters of the two enlargements are practically equal,[1] in the former the following variations are observed :

Cervical enlargement	vertical	3. mm.
	horizontal	4.5 "
Lumbar "	vertical	3. "
	horizontal	5. "

The gray matter also occupies more space in sections from the lumbar than in those from the cervical enlargement. The increase is also in the horizontal transverse dimension.

Cervical	vertical	1.75 mm.
	horizontal	2.5 "
Lumbar	vertical	1.5 "
	horizontal	3. "

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[1] Rabl-Rückhard, *Zeitschrift für Wissenschaftliche Zoölogie*, Bd. 30, H. 2, p. 341.

In this connection it may be important to record a fact which I have observed, with reference to the comparative thickness of the two enlargements of the spinal cord in nearly all the types of reptiles and batrachians. The thickness of the lumbar enlargement bears a certain relation to the power developed in the tail, exclusive of the comparative size of the posterior extremities, for example:

Alligator—Lumbar equals cervical.
Iguana[1]—Lumbar exceeds cervical.
Anolius—Cervical equals lumbar.
Skinks—Cervical exceeds lumbar.
Heloderma—Cervical exceeds lumbar.
All Turtles—Cervical exceeds lumbar.
Tailed Batrachians—Cervical equals lumbar.
Tailless Batrachians—Cervical exceeds lumbar.

The skinks and heloderma have very feeble tails. Among turtles the snapper is provided with a powerful tail, and in this animal we find a development of the lumbar enlargement intermediate, in size and shape, between that of the common land turtle, for example, and the alligator.

TAILED BATRACHIANS.

I would here ask attention to an important clause in the law about the comparative size of nuclei, which I have elsewhere ventured to formulate. "The nuclei of the so-called motor cells of the central nervous system have, *in the same individual*, average diameters, which are proportional to the power developed in the related muscles." The nuclei in the nerve cells of the mouse may be found to be twice as large as those in homologous cells of the elephant without affecting the above proposition. No claim is made, as one critic has inferred, that powerful or active animals have larger nuclei in their nerve cells than weak or sluggish ones, but simply that, in one and the same individual, these nuclei vary in average size, in accordance with the muscular energy to which, by means of their cell prolongations, they are supposed, in some way, to be related.

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[1] As already stated, the posterior limbs are larger, and, compared with the anterior limbs, more powerful in the iguana than in the alligator.

To show that I am not alone in regarding the nucleus as probably constituting the true nerve-cell, I take the liberty of quoting the following passage from an able article by Dr. H. D. Schmidt "On the structure and function of the ganglionic bodies of the cerebro-spinal axis," published in this JOURNAL for January, 1879, p. 20: "It seems obvious that nature should have assigned a particular function to a body of a constitution as complicated as that of the so-called 'nucleus of the ganglionic cell'; and I cannot forbear to point again to the fact, that if any part of the ganglionic body deserves the name of a nervous cell at all, it is the nucleus; for it alone represents an organic cell in the true sense of the word."

In the three species of tailed batrachians enumerated in the heading of this article, hellbender, siren, and salamander, the nuclei present a remarkably large appearance. The same peculiarity has been noticed by Stieda[1] in the axolotl, Schmidt[2] in amphiuma, and Spitzka[3] in menobranchus.

According to the measurements of Stieda the cells of the spinal cord (axolotl) have nuclei from .024 to .030 mm. in diameter. In the batrachians which I have studied the nuclei in spinal-cord cells measure as follows:

Rana Pipiens, lumbar enlargement	.025 x .030	mm.
Average, 7 x 9 divisions, $\frac{1}{400}$ mm. each, or	.0175 x .0225	"
Rana Halecina, average	.015 x .02	"
Menopoma, largest nuclei	.025 x .0325	"
Average, 7 x 9 divisions, or	.0175 x .0225	"
Siren, largest nuclei	.025 x .0275	"

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[1] Ueber den Bau des Centralnervensystemes der Amphibien und Reptilien, 1875.

[2] *Loc. cit.*, this JOURNAL, Jan., 1879.

[3] Transactions of the American Neurological Association, June, 1878.

Average	.015 x .025	mm.
Salamander (5 in. long), largest	.025 x .0275	“
Average	.015 x .025	“

It is probable from the above table that there is a remarkable similarity in the dimensions of the nuclei in the nerve cells of batrachians, at least for the spinal cord. The following represents the variation in size to be observed in one of the tailed orders, menopoma.

	AVERAGE.
Spinal cord, cervical region	7. x 9.
“ lumbar “	7. x 9.
“ middle caudal region	6. x 8.
Probable origin of motor root of trigeminus	8. x 9.
Nuclei in cells near oculomotorius	5. x 7.

Nuclei of connective tissue	(5. x 5.)—(6. x 7.)
“ in blood globules	3. x 4.
“ “ cells of superior horns	6. x 7.
“ “ “ “ corpus striatum	6. x 7.

Compared with the neighboring masses of nuclei, those which appear to be related to the oculomotorius are smaller in menopoma than in rana pipiens. The optic lobes in the siren, seen in vertical transverse section, resemble closely fig. 14 in Stieda's work on the axolotl. In menopoma, instead of being elliptical as in siren and axolotl, the aquæductus Sylvii opens laterally much as in frogs and turtles.

In the spinal cord the homologue of the ligamentum denticulatum, elsewhere recently described by me as existing in ophidia and sauria is present, but in a still less degree of development than in the iguanidæ.

SERPENTS.

Since my last publication on this subject I have measured the nuclei in nerve cells from the various parts of the nervous system of three species of serpents.

The gopher snake (Spilotes Erebennus), water snake (Nerodia Fasciata), and the rattlesnake (Crotalus Adamanteus).

Grimm[1] does not publish measurements of the nuclei, but gives for the dimensions of the large spinal-cord nerve cells .024—.04 by .009—.015 mm.

I have recorded the following average dimensions for the rattlesnake, and, as usual, in eye-piece divisions.

Nuclei in cells of origin of trigeminus motor root .	4.5 x 5.
" " " oculomotorius and trochlearis,	2.5 x 3.
" " spinal cord	4. x 5.
" " basal group near and in front of hypoglossus	5. x 6.

They apply to all three species.

Since writing the foregoing pages I have received three fine specimens of menobranchus (Necturus Lateralis). Portions of the spinal cord from one of the specimens were devoted to the study of the nerve cells in the fresh state. Minute sections, including the gray substance, were removed by scissors, and after remaining a few minutes in carmine, were teased apart with needles, and the ganglion cells brought into view and isolated by agitation in glycerine and water. No other reagent was employed. Several slides were obtained, each showing a large number of cells, with large, well-stained granular nuclei. Although the protoplasm of the cell was but feebly colored its granular structure was apparent. A fibrillary arrangement of the granules, like that so well represented by the plates of Schmidt, was not visible, this being doubtless due to the absence of bichromate. Under the object-cover the nuclei appeared like broad ovoid bodies, and measured from 9 x 10 to 13 x 14 divisions.

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[1] J. Grimm, "Ein Beitrag zur Kenntniss vom Bau des Rückenmarkes von Vipera Berus," *Archiv für Anat. u. Phys.*, 1864, p. 502.

A slight excess of menstruum was used in all cases, and was pressed out beyond the edges of the cover, carrying with it many of the large isolated cells.

Examination of these uncovered portions of the liquid revealed the fact that the nuclei were much flattened in form. There being here little impediment to the free motion of the elements, by inclining the stage of the microscope, and giving a judicious lateral inclination to the slide, many of the cells could be made to rotate, and so slowly in many cases that I was able to measure accurately all three diameters of their nuclei. It is almost certain that many, if not all, of the largest nuclei in the spinal-cord cells of menobranchus have the shape denoted by the following measurements:

Length,	13 x 14 divisions	. .	Equivalent to, say,
Breadth,	9 x 10 "	. . . .	9 x 10
Thickness,	5 x 6 "	. . .	when spheroidal.

If the correctness of this observation be confirmed in other specimens, it will be evident that the immense size of these nuclei, seen in sections and in covered preparations, depends solely upon the area of surface which, under these circumstances, is most often presented to vision, or is most often noticed.

It is certain that no such degree of flattening of the nuclei is to be observed in anourous batrachians, even when the cells are freshly prepared and by the same method as just described.